Effect of Pt layer thickness on perpendicular magnetic anisotropy in ultrathin Co/Pt multilayers

P. D. Kulkarni, M. Krishnan, H. C. Barshilia, and P. Chowdhury

Citation: AIP Conf. Proc. **1512**, 1144 (2013); doi: 10.1063/1.4791452
View online: http://dx.doi.org/10.1063/1.4791452
View Table of Contents: http://proceedings.aip.org/dbt/dbt.jsp?KEY=APCPCS&Volume=1512&Issue=1
Published by the American Institute of Physics.

Effect of Pt layer thickness on perpendicular magnetic anisotropy in ultrathin Co/Pt multilayers

P. D. Kulkarni, M. Krishnan, H. C. Barshilia and P. Chowdhury*

Surface Engineering Division, National Aerospace Laboratories, CSIR, Bangalore 560017, India
**Email: pchowdhury@nal.res.in*

Abstract. Co/Pt multilayer structures with varying Pt layer thicknesses from 1.5 to 12 Å were deposited on Ta buffer layer by DC magnetron sputtering technique and both of their magnetic and structural properties were investigated. All the multilayers showed perpendicular magnetic anisotropy (PMA) and the enhancement in PMA is observed with increase in the Pt layer thickness. The structural investigation using XRD reveals the presence of single peak in all these multilayers, which indicate the formation of coherent Co/Pt (111) structure. The origin of PMA in these multilayer structure is due to the strain induced in the Co layer. From the full-width-half-maximum (FWHM) of the XRD patterns it is observed that the grain size is increasing with increasing the Pt layer thickness. The influence of the enhancement of the grain size is then correlated with the measured M-H hysteresis behavior and subsequently the anisotropy energy.

Keywords: PMA, Co/Pt, strain.
PACS: 75.70.Cn, 75.80.+q, 81.15.Cd, 75.30.Gw

INTRODUCTION

The films with perpendicular magnetic anisotropy (PMA) have gained very much interest in past decade because of their several advantages over the films with in-plane anisotropy. The use of spin-valves and magnetic tunnel junctions with PMA provides enhanced recording density along with better thermal stability, lower threshold currents for spin transfer switching and current induced domain wall motion.

The PMA has been reported by people in several multilayer structures such as, Co/Pt, Co/Pd, Co/Cu, Cu/Ni[1]. It has been observed that the structures such as Co/Pt with their higher lattice misfit (> 8%) produced higher PMA values. In our previous studies, we have discussed thoroughly the effect of variation of Co layer thickness on the PMA of the Co/Pt multilayers[2]. Here, we are presenting the study on the effect of the Pt thickness variation on the PMA of the Co/Pt multilayers.

EXPERIMENTAL PROCEDURE

Co/Pt multilayers with the structure Ta(40Å)/ [Pt(t_{Pt}) / Co(2.1Å)]$_3$ / Pt(20Å) were deposited on Si (100) substrate by using ultra-high vacuum DC magnetron sputtering system with base pressure of ~ 5 x 10^{-9} torr. Ar pressure was maintained at 3.5 x 10^{-3} torr during the deposition. The films with different thicknesses of Pt layer (t_{Pt}) from 1.5 Å to 12 Å were deposited. Detailed experimental procedure was described elsewhere [2]. The M-H loops were measured by using the vibrating sample magnetometer (VSM). The structural characterizations were studied by X-ray diffraction (XRD) patterns.

RESULTS AND DISCUSSION

Figures 1(a) and (b) show the measured M-H loops with the applied magnetic field (H) in out-of-plane and in-plane directions of the film, respectively. It is observed that both the squareness of out-of-plane M-H loops and coercivity field (H_C) increase with increase in t_{Pt} value (Fig. 1(a)). This indicates the suppression of magnetic domain nucleation for higher t_{Pt} values[3]. All the deposited films exhibit out-of-plane loops with a remanence ratio of M_R/M_S = 1, indicating dominant net PMA. In case of the in-plane M-H loops (Fig. 1(b)), the systematic increase in the field required for the saturation of magnetization is observed. It indicates that the hard axis (which is along the in-plane direction) of magnetization becomes stronger with increase in t_{Pt}. These results an enhancement of PMA with t_{Pt}. The effective PMA energy can be calculated

SOLID STATE PHYSICS: Proceedings of the 57th DAE Solid State Physics Symposium 2012
AIP Conf. Proc. 1512, 1144-1145 (2013); doi: 10.1063/1.4791452

from the measured in-plane and out-of-plane M-H loops by using an equation,

$$K_{eff} = \frac{H_K M_S}{2}. \quad (1)$$

Here, H_K is the anisotropy field ($H_K = H_{S\parallel} - H_{S\perp}$, $H_{S\parallel}$ and $H_{S\perp}$ are the saturation fields corresponding to in-plane and out-of-plane measurements, respectively) and M_S is the effective saturation magnetization[2] which is almost constant in these films (2500 emu/cm^3 ± 10%). The K_{eff} calculated by using Eq. (1) is given in inset of Fig. 1(b). Interestingly, it is observed that the

Because of this induced strain, the magneto-elastic anisotropy gets developed which dominates the shape anisotropy of the film and resulting to PMA[1-3].

Inset of Fig. 2 shows the trend of full-width-half-maximum (FWHM) of the XRD patterns as function of t_{Pt}. It is observed that the FWHM is decreasing with increase in t_{Pt} values. This indicates that the increase in the grain size reduces the non-uniform strain present in the structure. This results in the increase in the magnetic domain size causing suppression of domain nucleation.

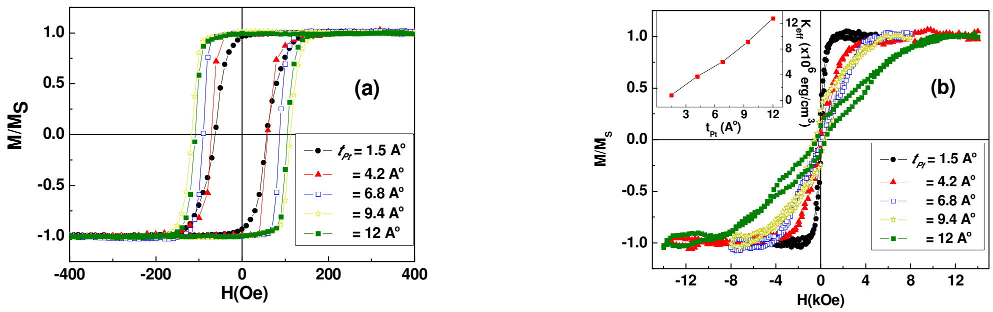

FIGURE 1. Measured out-of-plane (a) and in-plane (b) M-H loops of the multilayers with different t_{Pt}. Inset of (b) is the K_{eff} as a function of t_{Pt}.

K_{eff} increases linearly with t_{Pt}. With t_{Pt} = 12Å, the estimated value of K_{eff} in the multilayer is 1.3 x 10^7 erg/cm^3 which is the highest value so far reported to the best of our knowledge[2]. To correlate theses results, structural investigation was carried out. The

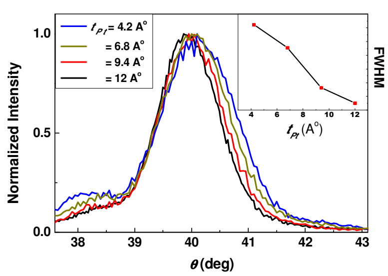

FIGURE 2. XRD patterns with different t_{Pt} values. Inset shows FWHM as a function of t_{Pt}.

XRD patterns of the films are shown in Fig. 2. It is to be noted that the XRD patterns have shown only single peak at 40±0.1^o near to bulk Pt (111) position (39.8^o) and there is no peak at bulk Co (111) position. This indicates the coherent growth of the Co/Pt (111) multilayer structure. As the Co layer thickness is small enough, the lattice misfit in Co and Pt (~10%) is compensated by initiation of strain in the layers[2,3].

CONCLUSION

The PMA in ultrathin Co/Pt multilayers was studied with varying the thickness of Pt layers. Irrespective of Pt layer thickness, the multilayer growth was found to be coherent. Though the structural investigations reveal 10 % strain in Co layer in all of these multilayers, however, non-uniform strain in Co-layer for lower t_{Pt} value results an reduction in PMA. This might be due to the formation of domain nucleation at lower field.

ACKNOWLEDGMENTS

This work is supported by the Director, National Aerospace Laboratories, Bangalore. Authors are grateful for the financial support by Department of Science and Technology (DST) and National Program on Micro and Smart Structures (NPMASS).

REFERENCES

1. M. T. Johnson et al., *Rep. Prog. Phys.* **59**,1404 (1996).
2. P. Chowdhury et al., *J. Appl. Phys.* **112,** 023912 (2012).
3. S. Emori and Geoffrey S. D. Beach, *J. Appl. Phys.* **110,** 033919 (201).